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CO_2 miscible flooding for Aswad Oil Field

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ABSTRACT

The current renewed interest on research and development of EOR processes and their oilfield implementation would allow targeting significant volumes of oil accumulations that have been left behind in mature reservoirs after primary and secondary oil recovery operations.

During the life of a producing oil field, several production stages are encountered. Initially, when a field is brought into production, oil flows naturally to the surface due to existing reservoir pressure in the primary phase. As reservoir pressure drops, water is typically injected to boost the pressure to displace the oil in the secondary phase. Lastly, the remaining oil can be recovered by a variety of means such as CO2 injection, natural gas miscible injection, and steam recovery in the final tertiary or enhanced oil recovery (EOR) phase.

The main parameter for determination of the possibilities to enhance oil recovery by e.g. CO2 injection into a specific oil field is the measurement of Minimum Miscibility Pressure (MMP). This pressure is the lowest pressure for which a gas can obtain miscibility through a multi contact process with a given oil reservoir at the reservoir temperature. The oil formation to which the process is applied must be operated at or above the MMP. And we obtained by using PVTi software.

The objective of this paper is to check if the Aswad field is suited for the application of CO2 miscible flooding and to see how much the recovery factor will increase after applying this EOR technique and to obtain the best WAG ratio and injection rate.

***Keywords*:** EOR, CO_2, MMP, Oil recovery, WAG ratio Production performance.

1. Introduction

Enhanced oil recovery (EOR) processes include all methods that use external sources of energy and/or materials to recover oil that cannot be produced, economically by conventional means.

And CO_2 flooding consists of injecting large quantities of CO_2 (15% or more hydrocarbon pore volumes) in the reservoir to form a miscible flood.

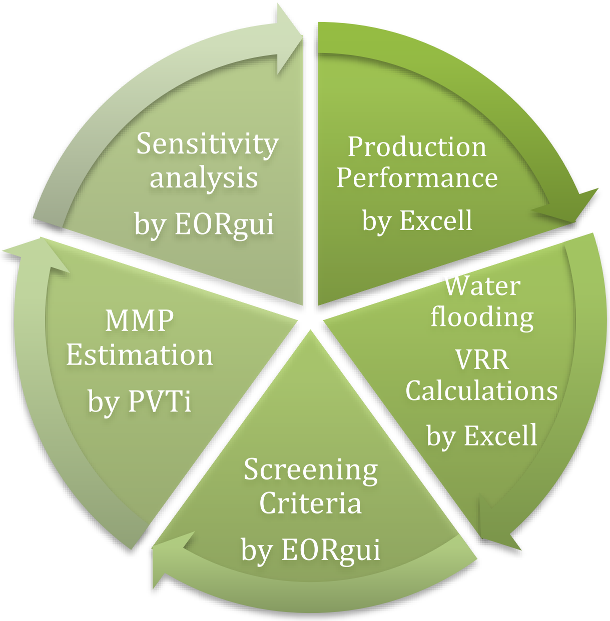
The field that has been studied in this paper is Aswad field., the field is located in Sirte basin, south-east sirt basin, south of Zella field, operated by Zwitina oil company. The production from Aswad oil field started in October 1978. The field has gone through primary and secondary recovery mechanisms. The Aswad structure is a fault-bounded anticline that trends in a NW-SE direction. Table 1 below shows the fluid and rock properties of Aswad field.

Table 1: Rock and Fluid Properties with data for Aswad field

Parameter	Value	Unit
Initial Pressure, (P_i)	2698	Psia
Current Pressure, (P)	2179	Psia
Saturation Pressure, ($P_{sat.}$)	1470	Psia
Original Oil In Place, (N)	96.30	MMSTB
Original Gas In Place, (G)	81.70	BSCF
Initial Oil Reserves, (N_p)	37.70	MMSTB
Gas Oil Ratio, (GOR)	1400	SCF/STB
Gas Solubility	796	SCF/STB
Oil Gravity, (API)	46.70	° API
Gas Formation Volume Factor (B_g)	0.018	cf/Scf
Oil Formation Volume Factor (B_o)	1.561	RB/STB
Oil Viscosity, (μ_o)	0.346	cp
Average Net Pay, (h)	49.50	ft
Average Porosity, ($\phi_{avg.}$)	20.50	%
Average Permeability, ($k_{avg.}$)	11.68	md
Initial Water Saturation, (S_{wi})	25.60	%

2. Methodology

The technique that we used in this paper is divided into several steps. Firstly, we analysed the production performance of the field to understand the performance of reservoir, and remaining oil reserve and other important parameters such as WC and GOR, in the next step we evaluate the water flooding project by the calculation of voidage replacement ratio VRR Because we will use the same pattern that is used in the water flooding project to inject the CO2 because we didn't do a simulation to the reservoir (because we don't have the reservoir model) to select the best pattern that provide the highest production rate, in the third step we did a screening to the field by using (Rock and Fluid Properties) in order to check if the Aswad field is suited for the application of CO2 miscible flooding, by using EORgui software, and in the following step we Estimate the Minimum Miscibility Pressure for CO2 with oil by building EOS modelling via PVTi software, and finally we predict the future oil production after applying CO2 miscible flooding and we did a sensitivity analysis to see the best WAAG ratio and Injection rate that gives the highest recovery factor. The chart below gives summary of the steps



Figure(1) Methodology of the study

3. Results and discussion

3.1. Production Performance

Aswad Oil Field Started Production in October 1978 by drilling First Well B-01 and then Injection started in June 1979, The Total Drilled Wells are nineteen Wells, and four Wells were Dry wells and were abandoned. Figures 2, 3, 4 and 5 show the production performance of Aswad oil field as well as injection performance.

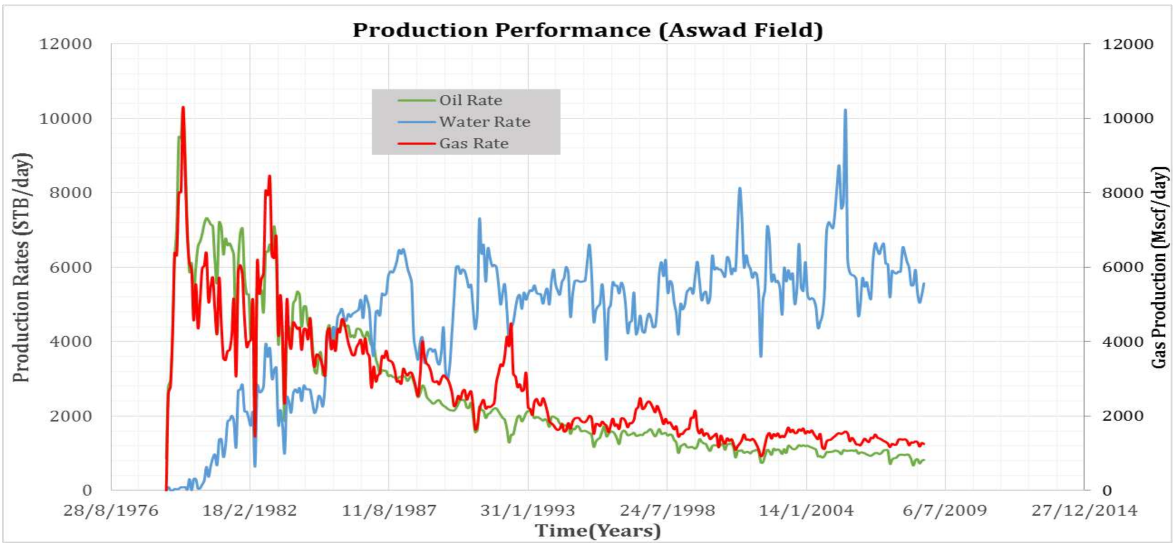


Figure (2) Production rates of Aswad field

Figure 2 shows the production rate for oil, water and gas, the oil rate started high reach to 10,000 STB/day then declined to 6000 STB/day, but after water injection increased to 8000STB/day, finally declined to about 800 STB/day . To be noticed that the main potential of the reservoir is water injection.

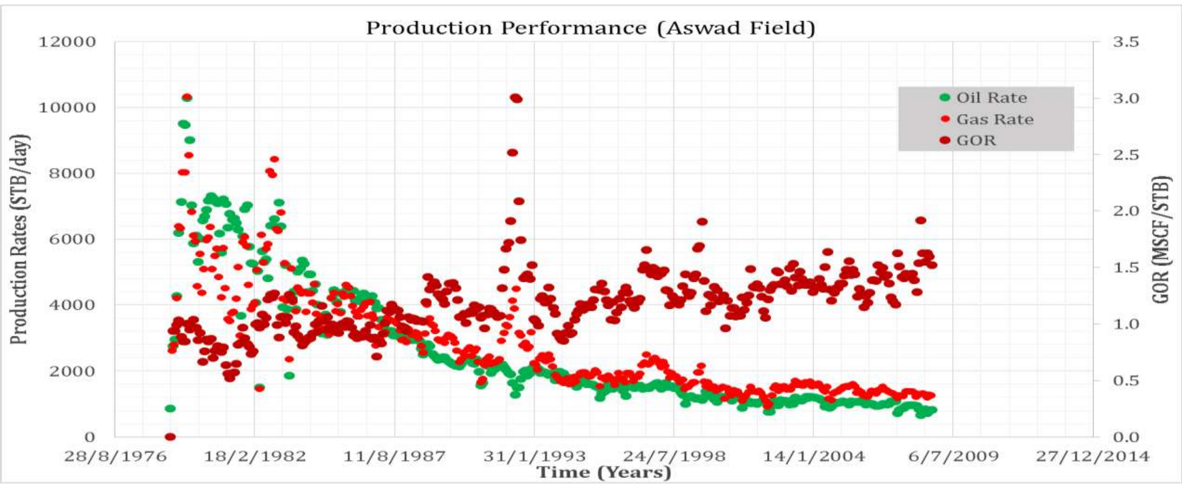


Figure (3) Production Performance of Aswad field

Figure 3 shows the GOR performance with oil and gas rates, the GOR is mainly stabilize at first period of reservoir life and after decrease in the pressure the GOR increased but after injection water the pressure increase and GOR returned to stabilization at about 1500 SCF/STB. The reservoir is under-saturated oil reservoir.

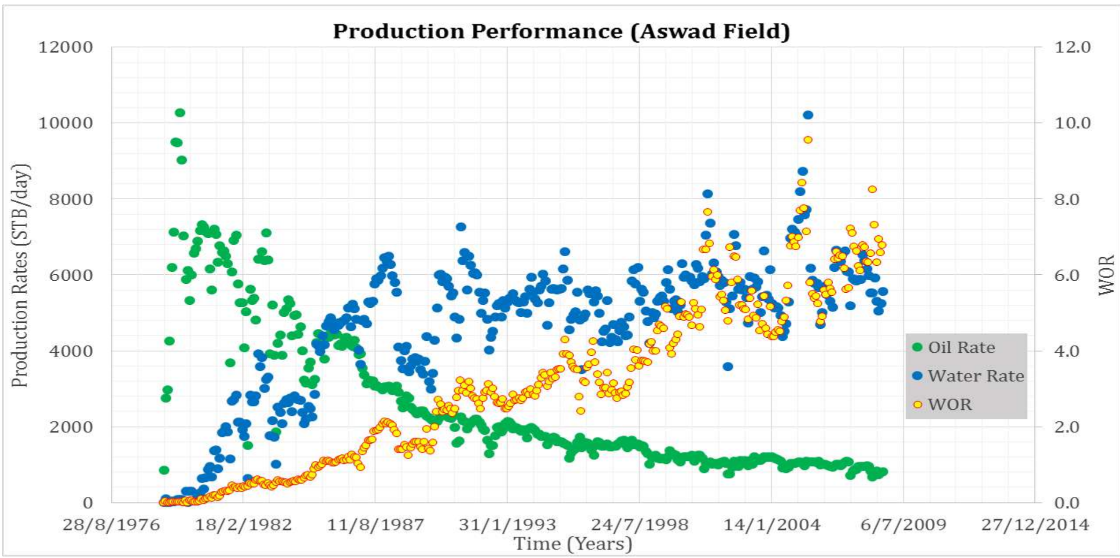


Figure (4) Production Performance of Aswad field

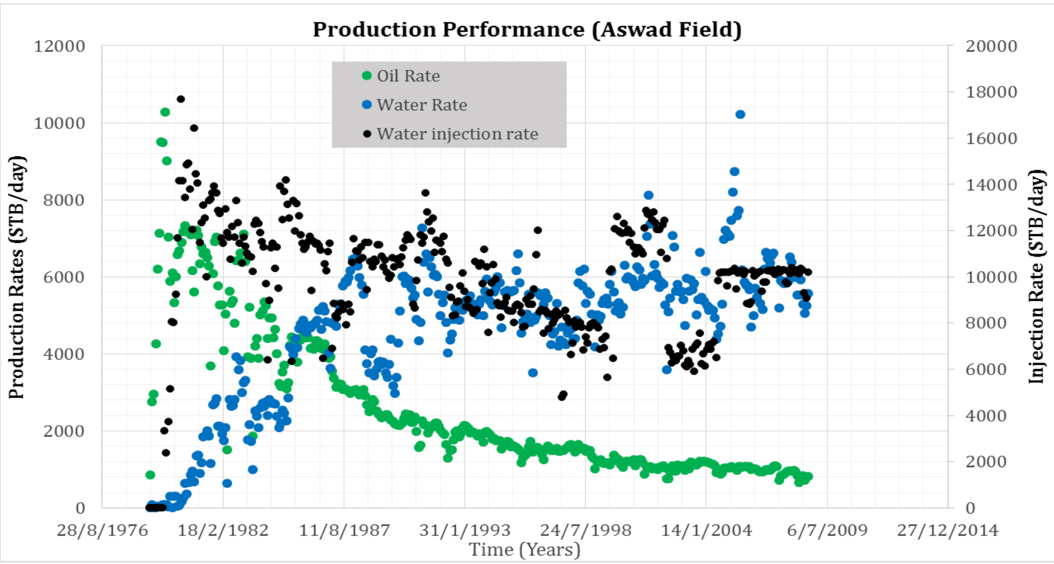


Figure (5) Production Performance of Aswad field

Figures 4 and 5 show the water rate performance as produced and the water injected. The injection of water started at early time of field life with high injection rate to support the reservoir pressure. After analysis of production performance, the results were summarized up to 31/08/2008:

Table 2: Aswad field data

OIIP	96.3	MMSTB
Reserve	37.7	MMSTB
RF	39.15	%
Current RF	29	%
Current Np	28.313	MMSTB
Gas rate	1249.032	Mscf/day
Oil rate	820.935	STB/day
Water rate	5567	STB/day
WC	87.149	%
WOR	6.781	Unitless
GOR	1.521	Mscf/STB

3.2. Water flooding performance evaluation

As shown in production performance analysis the reservoir was flooded by water form early life, the performance of water flooding should be considered, to ensure that reservoir fractures that making water losing in the reservoir.

The main factor to evaluate the water flooding performance is called Voidage replacement ratio (VRR), calculated by:

$$\mathrm{VRR} = \frac{q_i . B_w}{q_o . B_o + q_w B_w + q_o (\mathrm{GOR} - \mathrm{Rs}) B_g}$$

The performance of water flooding is shown in figure (4.7), its shows that VRR almost 1 for different period of flooding stages, with average VRR=1.165, that make indication for performance of water flooding was good.

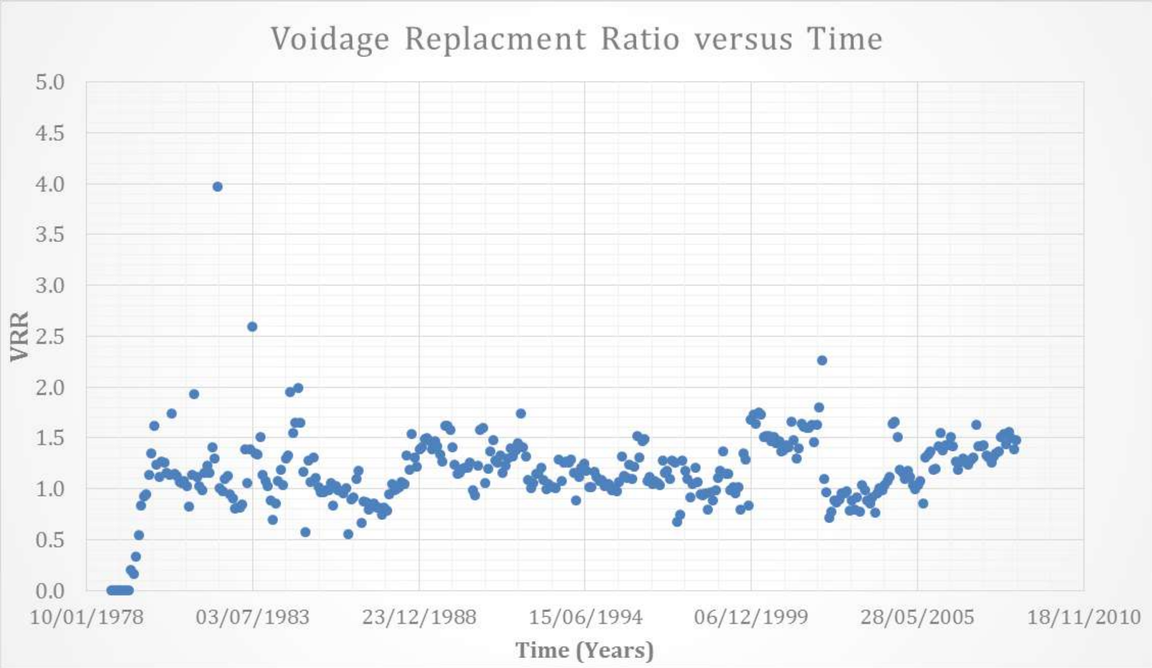


Figure (6) Voidage Replacement Ratio (VRR) with time

3.3. EOR Screening Criteria

Screening criteria used to select the optimum EOR method to apply for Aswad field. This selection is done by using EORgui software.

Figure 7 shows EOR methods screening for Aswad field. The input data that are required for the EOR selection are present in table 3.

Table 3: Input data for the screening

API	46.7°
Oil viscosity	0.346 cp
Oil saturation	0.5417
Lithology	Carbonate
Net thickness	49.5 ft
Total Depth	6425 ft
Temperature	185 F
Average permeability	11.68 md

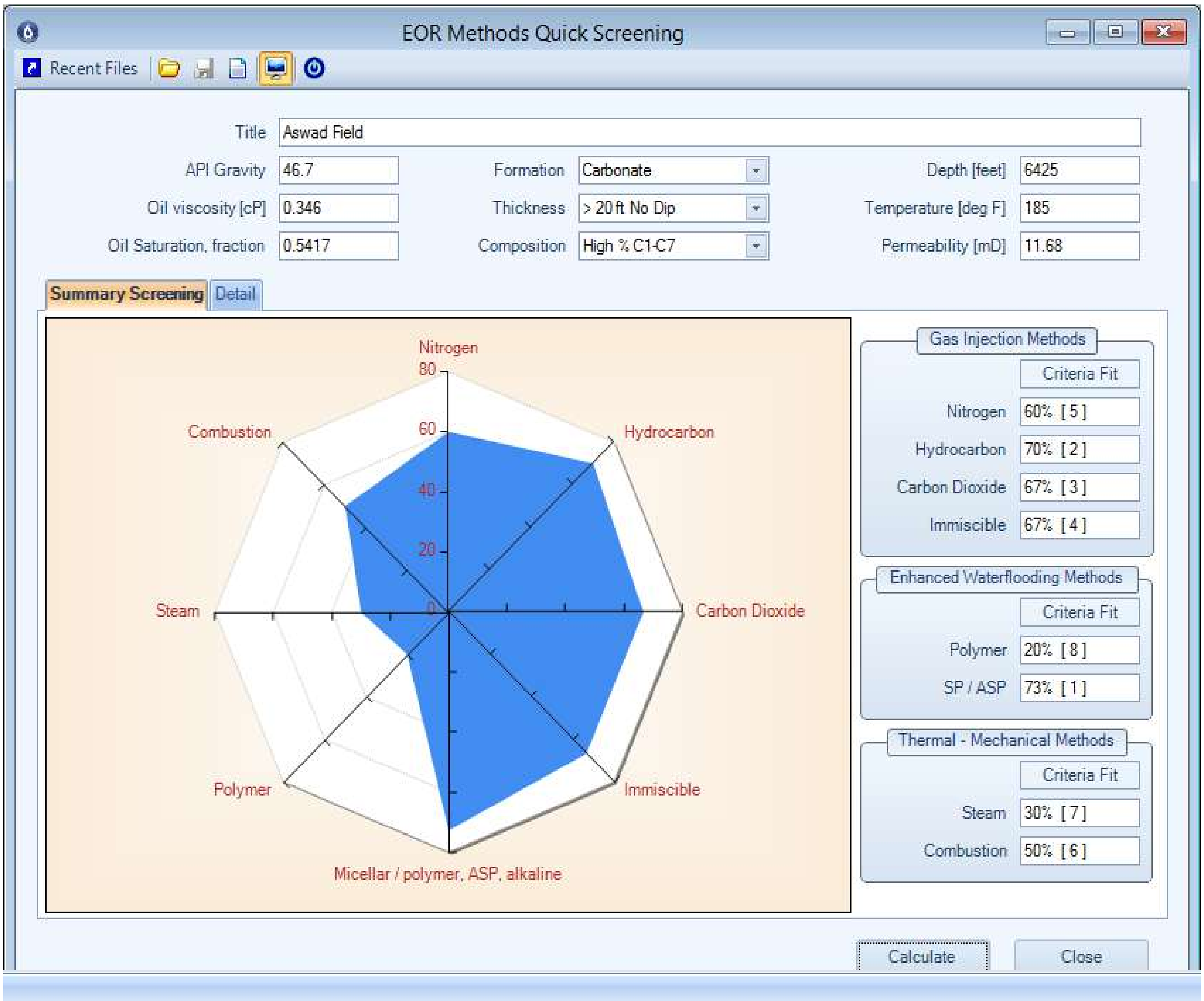
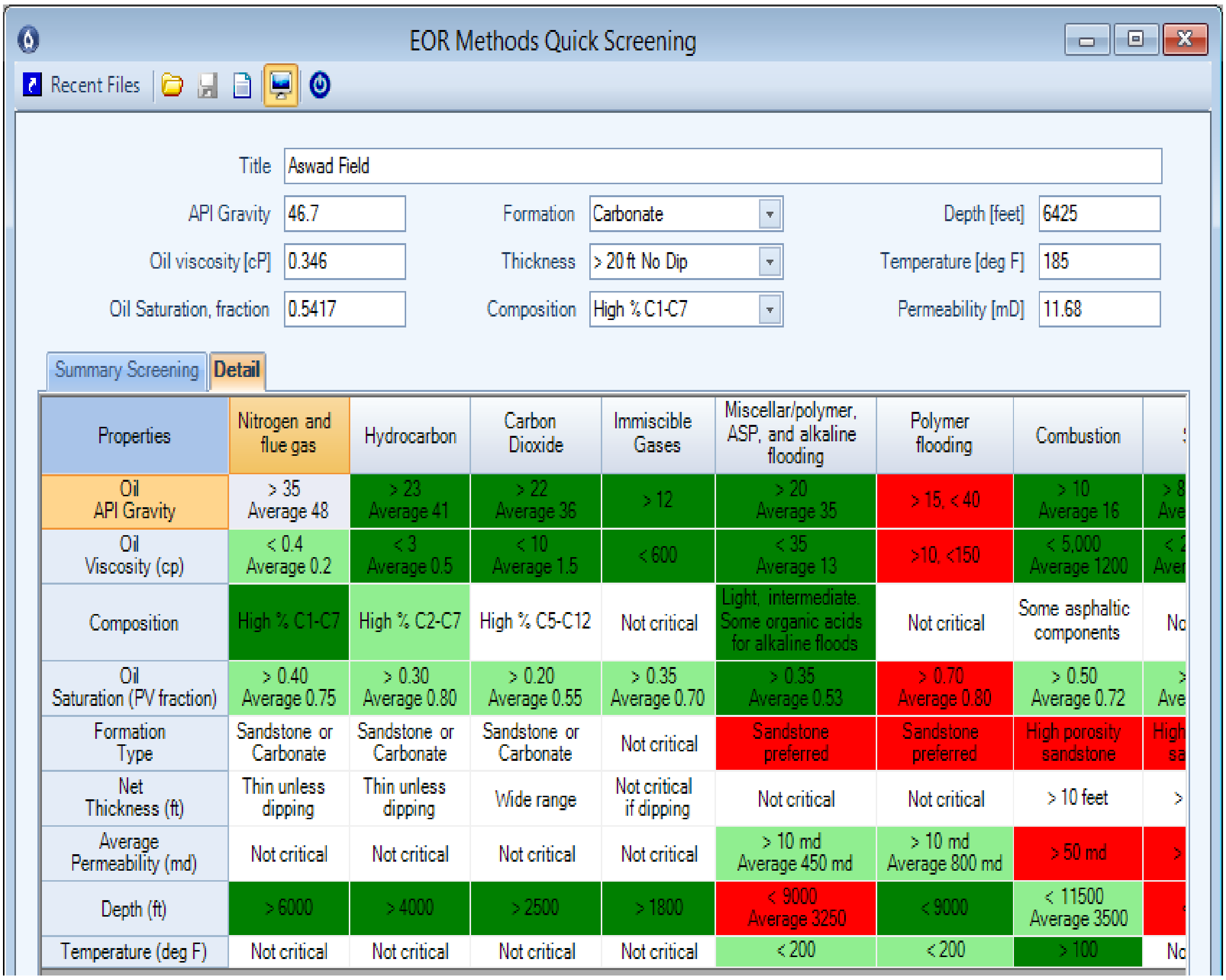


Figure (7) Summary screening of Aswad oil field


EOR Methods Quick Screening

Recent Files

Title: Aswad Field

API Gravity: 46.7 | Formation: Carbonate | Depth [feet]: 6425

Oil viscosity [cP]: 0.346 | Thickness: > 20 ft No Dip | Temperature [deg F]: 185

Oil Saturation, fraction: 0.5417 | Composition: High % C1-C7 | Permeability [mD]: 11.68

Summary Screening | Detail

Properties	Nitrogen and flue gas	Hydrocarbon	Carbon Dioxide	Immiscible Gases	Miscellar/polymer, ASP, and alkaline flooding	Polymer flooding	Combustion	
Oil API Gravity	> 35 Average 48	> 23 Average 41	> 22 Average 36	> 12	> 20 Average 35	> 15, < 40	> 10 Average 16	> 8 Ave
Oil Viscosity (cp)	< 0.4 Average 0.2	< 3 Average 0.5	< 10 Average 1.5	< 600	< 35 Average 13	>10, <150	< 5,000 Average 1200	< Aver
Composition	High % C1-C7	High % C2-C7	High % C5-C12	Not critical	Light, intermediate. Some organic acids for alkaline floods	Not critical	Some asphaltic components	No
Oil Saturation (PV fraction)	> 0.40 Average 0.75	> 0.30 Average 0.80	> 0.20 Average 0.55	> 0.35 Average 0.70	> 0.35 Average 0.53	> 0.70 Average 0.80	> 0.50 Average 0.72	> Ave
Formation Type	Sandstone or Carbonate	Sandstone or Carbonate	Sandstone or Carbonate	Not critical	Sandstone preferred	Sandstone preferred	High porosity sandstone	High sa
Net Thickness (ft)	Thin unless dipping	Thin unless dipping	Wide range	Not critical if dipping	Not critical	Not critical	> 10 feet	>
Average Permeability (md)	Not critical	Not critical	Not critical	Not critical	> 10 md Average 450 md	> 10 md Average 800 md	> 50 md	>
Depth (ft)	> 6000	> 4000	> 2500	> 1800	< 9000 Average 3250	< 9000	< 11500 Average 3500	
Temperature (deg F)	Not critical	Not critical	Not critical	Not critical	< 200	< 200	> 100	No

Figure (8) Detail screening of Aswad oil field

As can be seen from figure 7, the left hand side column represents the properties (input data) that effect on the selection of EOR method. The top row in the same figure shows the different EOR processes. Red block means the property out of limitation of method, Green block means the property out of limitation of the method, light green block means slightly effect of property on method and whit block means no effect of property on method.

The above screens for EORgui screening shows high ability to applying CO2Miscibility flooding for this field about 67% so this is a good sign

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3.4. Minimum miscibility pressure (MMP) calculation

To ensure miscibility between injection gas and oil, the pressure should be higher than MMP that can be measured at laboratory by using slim tube test, but when test is missing, the correlation and EOS modelling can be used.

In our study, we build EOS model by using PVTi software to calculate MMP.After input the laboratory tests in PVTi, then select EOS (Soave-Redlich-Kwong (3-Parm) and Lohrenz-Bray-Clark Viscosity Correlation andsplitting the C7+to three fraction to tuning the modelling

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- Tuned bubble point pressure = 1461.2426PSIG
- Measured bubble point pressure = 1462.0000PSIG

Multiple contact miscibility pressure (MMP) = 2065.0546 PSIG

3.5. Sensitivity analysis

Enhanced oil recovery through the injection of CO2 as a tertiary recovery mechanism, with water flooding as Water altering gas (WAG), will be studied to predict the amount of oil that can be produced. The main factors that may be effect on this process are injection fluid rate and WAG ratio, so the sensitivity will be run to investigate the optimum injection rate and WAG ratio that gives high Recovery factor. We first used WAG ratio 1and change the injection rate to obtain the injection rate that provide the highest recovery factor.

Table 4: results of WAG ratio 1 and different injection rate

WAG ratio	Injection rate(bbl/day)	Time	RF (%)	NP MMSTB	WC (%)
1	7500	1/9/2035	35.58	34.26	96.69
1	10000	1/2/2030	35.75	34.42	97.57
1	12500	1/11/2025	35.71	34.38	98.20

The table shows that the injection rate that gives highest recovery factor is 10000(bbl/day). So we going to change the WAG ratio and hold the injection rate at 10000(bbl/day).

Table 4: results of injection rate 10000bbl/day and different WAG ratios

Injection rate(bbl/day)	WAG ratio	Time	RF (%	NP MMSTB	WC (%)
10000	0.5	1/8/2029	35.72	34.39	96.87
10000	1	1/2/2030	35.75	34.42	97.57
10000	1.5	1/7/2031	35.81	34.48	97.69

The best WAG ratio that gives the highest recovery factor is 1.5

3. Conclusion

With production from many mature oil fields such as
Aswad

field, the declining and approaching tail production, the field owners have to consider enhanced oil recovery as a way of recovering more oil from the fields. From the above screening, enhanced oil recovery through the injection of CO2 as a tertiary recovery mechanism is preferable for Asawd field.

CO2 injection has the potential to recover more oil 6% more, extend the field life and increase the profitability of the field. The optimum injection rate is 10,000 STB, by WAG ratio1.5, to reach to 35.81% recovery factor and water cut 97.69%.

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